

Topic 10: Organic Chemistry: Halogenoalkanes, Alcohols and Spectra

Related topics in Units 4 and 5 will assume knowledge of this material.

10A: General principles

Students will be assessed on their ability to:

10.1	be able to classify reactions (including those in Unit 1) as addition, elimination, substitution, oxidation, reduction, hydrolysis or polymerisation
	<p>Addition Reactions Two reactant species combine together to form a single product species A general equation is: $A + B \rightarrow C$</p> <p>Example: ethene and bromine $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$</p>
	<p>Elimination Reactions Two atoms or groups (often water molecules) are removed (eliminated) from the organic molecule A general equation is:</p> $ \begin{array}{ccccccc} & H & H & H & H & & \\ & & & & & & \\ - & C & - C & - C & - C & - & \\ & & & & & & \\ & H & X & Y & H & & \end{array} \longrightarrow \begin{array}{ccccccc} & H & H & H & H & & \\ & & & & & & \\ - & C & - C = C & - C & - & & \\ & & & & & & \\ & H & & H & & & \end{array} + XY $
	<p>Substitution Reactions Two reactant species combine together to form two product species A general equation is: $A + B \rightarrow C + D$</p>
<p>Acidified potassium manganate (VII) will oxidise an alkene to a diol Acidified potassium dichromate will oxidise a primary or secondary alcohol</p>	<p>Oxidation Reactions One organic compound is oxidized (either loses hydrogen or gains oxygen) by an inorganic reagent A common example is: <i>The oxidation of ethanol by potassium dichromate(VI) and sulfuric acid</i> $C_2H_5OH + [O] \rightarrow CH_3CHO + H_2O$</p>
	<p>Reduction Reactions (is addition too!) An organic compound is reduced (gain hydrogen or lose oxygen), sometimes by hydrogen gas and a catalyst or sometimes by an inorganic reagent A common example is: <i>The reduction of an alkene to an alkane by hydrogen gas and a nickel catalyst</i> $C_2H_4 + H_2 \rightarrow C_2H_6$</p>
	<p>Hydrolysis Reactions (is substitution too!) An organic compound is reacted with water where the OH group of water replaces an atom or group in the organic compound A general equation is: $RX + H_2O \rightarrow ROH + HX$</p>
	<p>Polymerisation Reactions For IAS Level, you will only need to know addition polymerization which is when large numbers of a reactant molecule react together to form one large product molecule A general equation is:</p> $ n \begin{array}{ccc} W & & X \\ & \diagdown \quad \diagup & \\ & C = C & \\ & \diagup \quad \diagdown & \\ Y & & Z \end{array} \longrightarrow \left[\begin{array}{cc} W & X \\ & \\ -C & -C- \\ & \\ Y & Z \end{array} \right]_n $

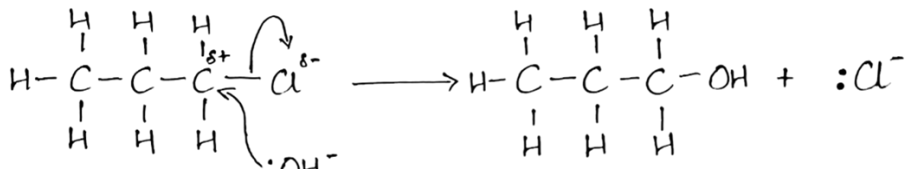
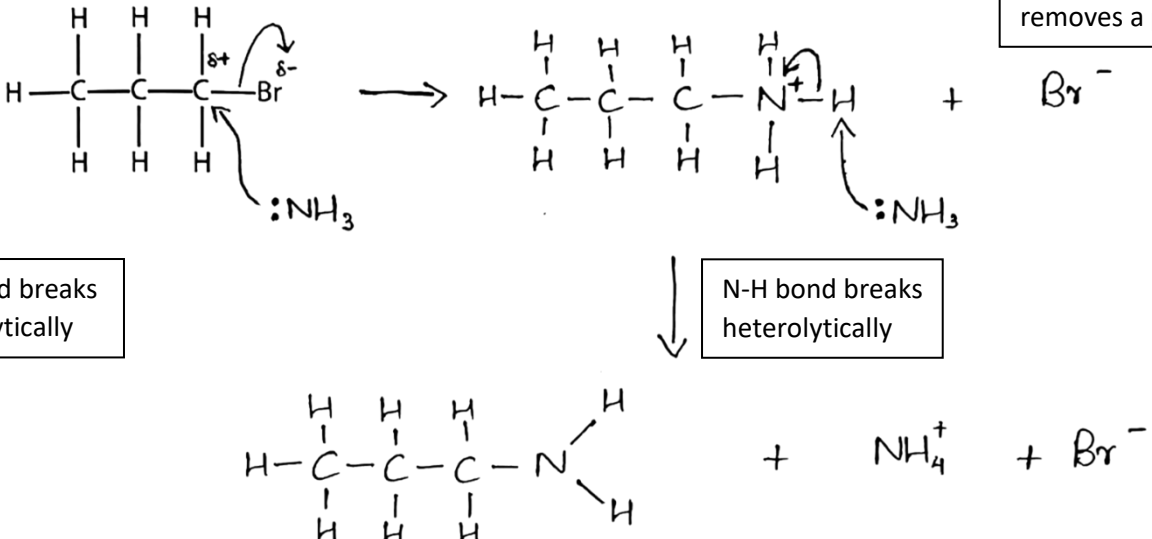
10.2	understand the concept of a reaction mechanism
	<p>For IAS Level, you will need to know 3 types of mechanisms:</p> <ol style="list-style-type: none"> 1. Free radical substitution of alkanes (homolytic) 2. Electrophilic substitution of alkenes (heterolytic) 3. Nucleophilic substitution in halogenoalkanes (heterolytic)
10.3	understand that heterolytic bond breaking results in species that are electrophiles or nucleophiles
	<p>Heterolytic bond breaking, in mechanism 2 and 3, is when a covalent bond breaks and one atom keeps both electrons from the shared pair of electrons in the bond This atom becomes a negative ion (anion) and acts as a nucleophile The other atom becomes a positive ion (cation) and acts as an electrophile In mechanism 1, the attacking species are free radicals (Cl^\cdot) In mechanism 2, the attacking species are electrophiles (H^+ of HBr) In mechanism 3, the attacking species are nucleophiles (OH^-)</p>
10.4	know the definition of the term 'nucleophile'
	<p>A nucleophile is an (electron-rich) species that donates a lone pair of electrons to form a covalent bond with an electron-deficient atom Nucleophile means 'nucleus/positive charge loving' as nucleophiles are attracted to positively charged species</p>
10.5	understand the link between bond polarity and the type of reaction mechanism a compound will undergo
	<p>For mechanism 1 where reactants are alkanes and halogens which are mostly non-polar, type of bond breaking is likely to be homolytic For mechanism 2 where reactants are hydrogen halides and halogenoalkanes which are polar, type of bond breaking is likely to be heterolytic</p>

10B: Halogenoalkanes

Students will be assessed on their ability to:

10.6	understand the nomenclature of halogenoalkanes and be able to draw their structural, displayed and skeletal formulae									
	<p>General Formula of Halogenoalkanes: $C_nH_{2n+1}X$ where X represents a halogen atom (or) RX where R represents an alkyl group</p> <p>Simply put, based on the original alkane you put the prefix indicating the halogen Fluoro for F, Chloro for Cl, Bromo for Br, Iodo for I Example: 1-chloromethane or 2-bromo-2-methylpropane Note that substituents(displacing atoms) are listed alphabetically: meaning Bromo comes first, then Chloro, Fluoro, Iodo Note: Draw common halogenoalkanes</p>									
10.7	understand the distinction between primary, secondary and tertiary halogenoalkanes									
	<p>Halogenoalkanes can be classified as primary, secondary or tertiary depending on the number of carbon atoms attached to the C-X functional group</p> <table><tr><th>Primary</th><th>Secondary</th><th>Tertiary</th></tr><tr><td></td><td></td><td></td></tr><tr><td>When one carbon atom (or alkyl group) is attached to the carbon atom adjointed to the halogen</td><td>When two carbon atoms (or alkyl groups) is attached to the carbon atom adjointed to the halogen</td><td>When three carbon atoms (or alkyl groups) is attached to the carbon atom adjointed to the halogen</td></tr></table>	Primary	Secondary	Tertiary				When one carbon atom (or alkyl group) is attached to the carbon atom adjointed to the halogen	When two carbon atoms (or alkyl groups) is attached to the carbon atom adjointed to the halogen	When three carbon atoms (or alkyl groups) is attached to the carbon atom adjointed to the halogen
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10.8	<p>understand the reactions of halogenoalkanes with:</p> <ul style="list-style-type: none">i aqueous alkali, including KOH(aq) to produce alcohols (where the hydroxide ion acts as a nucleophile) (substitution)ii ethanolic potassium hydroxide to produce alkenes by an elimination reaction (where the hydroxide ion acts as a base) (elimination)iii aqueous silver nitrate in ethanol (where water acts as a nucleophile) (substitution)iv alcoholic ammonia under pressure to produce amines (where the ammonia acts as a nucleophile) (substitution)v alcoholic potassium cyanide to produce nitriles (where the cyanide ion acts as a nucleophile) (substitution) <p><i>Students should know this is an example of increasing the length of the carbon chain.</i></p>									

	Recall that a nucleophile is an electron-rich species that can donate a pair of electrons Rmb that nucleophile is 'nucleus loving'
i	<p>Nucleophilic Substitution with aqueous alkali (hydroxide ions)</p> <p>Nucleophile: OH⁻ ions Type: Hydrolysis reaction Mechanism: nucleophilic substitution (shown in 10.9i)</p> <p style="text-align: center;">$\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl} + \text{KOH} \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{KCl}$</p> <p>Change in functional gp. Halogenoalkane Alcohol</p> <p>Reagent: KOH or NaOH in <u>aqueous solution</u></p> <p>Conditions: Heat under reflux</p>
	<p>C-X bond breaks heterolytically</p> <p>Aqueous condition is crucial here as if you put in ethanol, an elimination reaction to form alkenes occurs</p>
ii	<p>Elimination with alcoholic alkali (OH⁻ ions)</p> <p>There is no nucleophile here, the OH⁻ ions act as a base here Type: Elimination</p> <p style="text-align: center;">$\text{CH}_3\text{-CHBr-CH}_2 + \text{KOH} \rightarrow \text{CH}_2\text{=CH-CH}_3 + \text{H}_2\text{O} + \text{KBr}$</p> <p>Change in functional gp. Halogenoalkane Alkene</p> <p>Reagent: KOH or NaOH in ethanol Conditions: Ethanolic, Heat under reflux</p>
iii	<p>Reaction with water (Hydrolysis)</p> <p>Hydrolysis is the splitting of a molecule (a halogenoalkane in this case) by a reaction with water</p> <p>Nucleophile: H₂O (weak nucleophile) Type: Hydrolysis Mechanism: nucleophilic substitution</p> <p style="text-align: center;">$\text{RX} + \text{H}_2\text{O} \rightarrow \text{ROH} + \text{HX}$</p> <p>Change in functional gp. Halogenoalkane Alcohol</p> <p>No color change can be seen</p> <p>OH⁻ ion is a stronger nucleophile than water</p> <p>When silver nitrate solution in ethanol is added to the solution, the Ag⁺ ions will react with the halide ions as soon as they form, forming precipitates We will look at this further in 10.10ii</p> <p style="text-align: center;">$\text{RX} + \text{H}_2\text{O} \rightarrow \text{ROH} + \text{HX} \quad (\text{or}) \quad \text{RX} + \text{H}_2\text{O} \rightarrow \text{ROH} + \text{H}^+ + \text{X}^-$</p> <p>When aqueous silver nitrate is added to the halogenoalkane, the halide leaving group combines with the silver ion to form a silver halide precipitate</p> <p style="text-align: center;">$\text{Ag}^+(\text{aq}) + \text{X}^-(\text{aq}) \rightarrow \text{AgX}(\text{s})$</p>
iv	<p>Nucleophilic substitution with ammonia</p> <p>Nucleophile: NH₃ Mechanism: nucleophilic substitution (shown in 10.9ii)</p> <p style="text-align: center;">$\text{CH}_3\text{CH}_2\text{CH}_2\text{Br} + 2\text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2 + \text{NH}_4\text{Br}$</p> <p>Change in functional gp. Primary Halogenoalkane Primary Amine</p> <p>Reagents: excess NH₃ in ethanol Conditions: ethanolic, heat under pressure in a sealed tube</p> <p>Further substitution reactions can occur between the halogenoalkane and the amines formed leading to a lower yield of the amine To produce a high yield of the amine, <u>ammonia is used in excess</u></p>

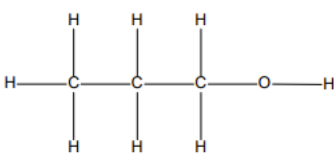
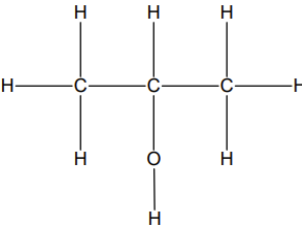
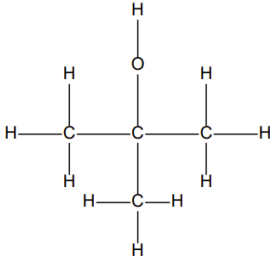
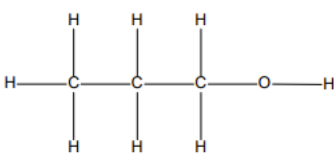
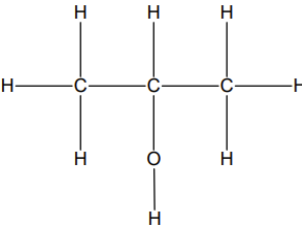
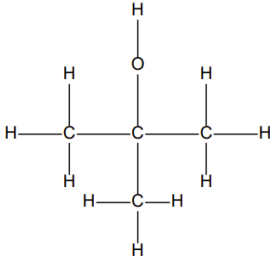
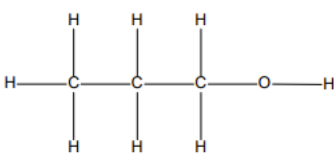
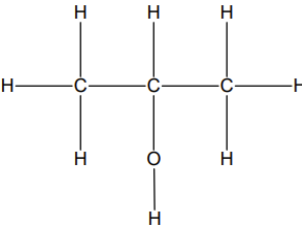
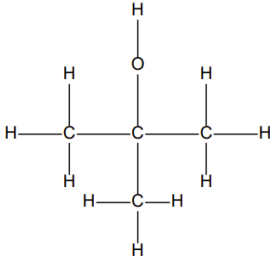
v	<p>Nucleophilic substitution of potassium cyanide</p> <p>Nucleophile: CN⁻ ion Mechanism: nucleophilic substitution</p> $\text{CH}_3\text{CH}_2\text{Br} + \text{KCN} \rightarrow \text{CH}_3\text{CH}_2\text{CN} + \text{KBr}$ <p>Change in functional gp. Halogenoalkane Nitriles Bromoethane Propanenitrile</p> <p>Reagents: KCN in ethanol (potassium cyanide) Conditions: Ethanolic, Heat under reflux</p>	<p>Notice the change from bromoethane to propan- this means the organic product contains <u>one more carbon atom</u> than the starting material</p>
10.9	<p>understand the mechanisms of the nucleophilic substitution reactions between primary halogenoalkanes and:</p> <p>i aqueous potassium hydroxide ii ammonia</p> <p><i>S_N1 and S_N2 substitution mechanisms will be tested in Unit 4.</i></p>	
	<p>A nucleophilic substitution reaction is a reaction in which a nucleophile attacks a carbon atom carrying a partial positive charge</p> <p>An atom that has a partial negative charge is replaced by the nucleophile</p> <p>Halogenoalkanes undergo nucleophilic substitution due to the polarity of the C-X bond</p>	
i	<p>A primary halogenoalkane reacts with aqueous alkali (potassium hydroxide) to form an alcohol</p> 	
ii	<p>A primary halogenoalkane reacts with ammonia to form a primary amine</p> <p>Mechanism is as follows:</p>  <div style="border: 1px solid black; padding: 2px; width: fit-content; margin-top: 10px;"> <p>Lone pair on ammonia attacks partially positive carbon</p> </div> <div style="border: 1px solid black; padding: 2px; width: fit-content; margin-top: 10px;"> <p>C-X bond breaks heterolytically</p> </div> <div style="border: 1px solid black; padding: 2px; width: fit-content; margin-top: 10px;"> <p>N-H bond breaks heterolytically</p> </div>	<p>Another NH₃ acts as a base and removes a proton</p>
10.10	<p>understand that experimental observations and data can be used to compare the relative rates of hydrolysis of:</p> <p>i primary, secondary and tertiary structural isomers of a halogenoalkane ii primary chloro-, bromo- and iodoalkanes using aqueous silver nitrate in ethanol</p>	

i	Measuring the rate of hydrolysis	
	Same halogen but different structure	Result
	Tertiary	fastest
	Secondary	
	Primary	slowest
	The rate of hydrolysis depends on Sn1 or Sn2 mechanism which fortunately for you- is not required for AS! But in A2!!	
ii	Measuring the rate of hydrolysis Aqueous silver nitrate solution is added a halogenoalkane (the halide leaving group combines with an Ag ⁺ ion) $\text{Ag}^+(\text{aq}) + \text{X}^-(\text{aq}) \rightarrow \text{AgX}(\text{s})$ The precipitate only forms when the halide ion has left the halogenoalkane and so the rate of formation of the precipitate can be used to compare the reactivity of the different halogenoalkanes The quicker the precipitate is formed, the faster the substitution reaction and the more reactive the haloalkane The rate of these substitution reactions depends on the strength of the C-X bond The weaker the bond, the easier it is to break and the faster the reaction (strength of the C-X bond depends on the polarity of the C-X bond and how much the halide ion is polarized- the more polarized it is, the weaker it is) Hence, C-I bond is the weakest as I ⁻ ion is the largest and has the same charge as the other halides which means it is the most polarized which results in the C-I bond being the weakest But this means Iodoalkanes are the most reactive (opposite trend of Gp. 7 reactivity)	

10.11	CORE PRACTICAL 5 Investigation of the rates of hydrolysis of some halogenoalkanes.
	Here is a rough outline for a method: <ul style="list-style-type: none"> - Set up 3 test tubes in a 50C water bath, with a mixture of ethanol and acidified silver nitrate solution - Add a few drops of a chloroalkane, bromoalkene and an iodoalkane to each test tube and start a stopwatch - Measure the time taken for the precipitate to form
10.12	know the trend in reactivity of primary, secondary and tertiary halogenoalkanes
	The order of reactivity will be: tertiary > secondary > primary
10.13	understand, in terms of bond enthalpy, the trend in reactivity of chloro-, bromo-and iodoalkanes
	C-Cl bond has the highest bond enthalpy, thus requires the most energy to break the bond and will also be the slowest, meaning chloroalkanes are the least reactive C-I bond has the lowest bond enthalpy, thus requires the least energy to break the bond and will be the fastest, meaning iodoalkanes are the most reactive
10.14	CORE PRACTICAL 6 Chlorination of 2-methylpropan-2-ol with concentrated hydrochloric acid.
	Further suggested practicals: <ul style="list-style-type: none"> i the use of silver nitrate solution to identify the halogen present in halogenoalkanes ii preparation of 1-bromobutane from butan-1-ol, potassium bromide and sulfuric acid

10C: Alcohols

Students will be assessed on their ability to:

10.15	understand the nomenclature of alcohols and be able to draw their structural, displayed and skeletal formulae									
	General formula: $C_nH_{2n+1}OH$									
10.16	understand the distinction between primary, secondary and tertiary alcohols									
	<p>Alcohols can be classified as primary, secondary or tertiary depending on the number of carbon atoms (alkyl groups) attached to the carbon with the O-H functional group</p> <table><tr><th>Primary</th><th>Secondary</th><th>Tertiary</th></tr><tr><td></td><td></td><td></td></tr><tr><td>When one carbon atom (or alkyl group) is attached to the carbon atom adjoined to the OH group</td><td>When two carbon atoms (or alkyl groups) is attached to the carbon atom adjoined to the OH group</td><td>When three carbon atoms (or alkyl groups) is attached to the carbon atom adjoined to the OH group</td></tr></table>	Primary	Secondary	Tertiary				When one carbon atom (or alkyl group) is attached to the carbon atom adjoined to the OH group	When two carbon atoms (or alkyl groups) is attached to the carbon atom adjoined to the OH group	When three carbon atoms (or alkyl groups) is attached to the carbon atom adjoined to the OH group
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10.17	<p>understand the reactions of alcohols with:</p> <ul style="list-style-type: none">i oxygen in air (combustion)ii halogenating agents<ul style="list-style-type: none">• PCl_5 to produce chloroalkanes (including its use as a qualitative test for the presence of the $-OH$ group)• 50% concentrated sulfuric acid and potassium bromide to produce bromoalkanes• red phosphorus and iodine to produce iodoalkanesiii concentrated phosphoric acid to form alkenes by elimination <p><i>Descriptions of the mechanisms of these reactions are not required.</i></p>									
i	<p>Combustion</p> <p>If combustion is complete, Alcohol + Oxygen \rightarrow Carbon dioxide + Water</p>									
ii	<p>Halogenation</p> <div><p>1. Chlorination (Test for OH group)</p><p>Reagent: Solid PCl_5 (phosphorous(V)chloride)</p><p>Conditions: Room temperature</p><p>A common example is: $CH_3CH_2OH + PCl_5 \rightarrow CH_3CH_2Cl + POCl_3 + HCl$</p><p>Change in functional group: Alcohol Halogenoalkane</p></div> <p>This reaction with PCl_5 (phosphorous(V)chloride) can be used as a test for alcohols (You would observe misty fumes of HCl produced that turns damp blue litmus paper red for presence of OH group)</p> <p>Chlorination of tertiary alcohols can be carried out in a different method that does not work with primary and secondary alcohols</p>									

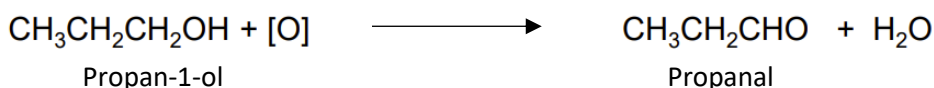
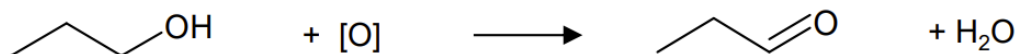
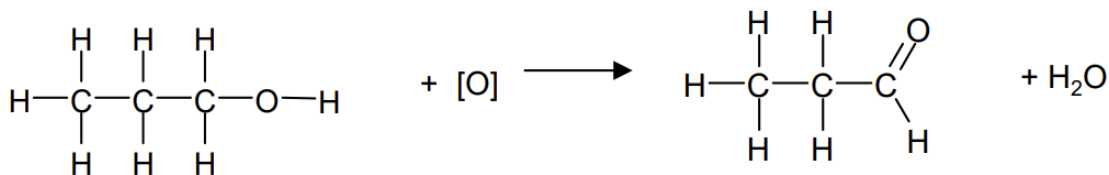
More concentrated sulfuric acid would oxidise bromide ions to bromine resulting in different products		<p>That is by mixing (shaking) with hydrochloric acid at room temperature A common example is: $(\text{CH}_3)_3\text{COH} + \text{HCl} \rightarrow (\text{CH}_3)_3\text{CCl} + \text{H}_2\text{O}$</p> <div><p>2. Bromination Reagents: KBr + 50% concentrated H_2SO_4 Conditions: Heat under reflux</p><p>This reaction is better written as two equations as the inorganic reactants first react together to form hydrogen bromide and potassium sulfate A common example is: $2\text{KBr} + \text{H}_2\text{SO}_4 \rightarrow \text{K}_2\text{SO}_4 + 2\text{HBr}$ And then the hydrogen bromide formed reacts with the alcohol $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{HBr} \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{H}_2\text{O}$</p></div> <div><p>3. Iodination Reagents: Damp red phosphorous + iodine Conditions: in aqueous solution and heated under reflux</p><p>As with bromination, it is better to write two equations as the inorganic reactants first react together to form phosphorous(III)oxide A common example is: $2\text{P} + 3\text{I}_2 \rightarrow 2\text{PI}_3$ And then the reaction with ethanol, forming phosphorous acid too! $3\text{C}_2\text{H}_5\text{OH} + \text{PI}_3 \rightarrow 3\text{C}_2\text{H}_5\text{I} + \text{H}_3\text{PO}_3$</p></div>
	iii	<div><p>Dehydration to Alkenes by Elimination Reagents: concentrated H_3PO_4 (phosphoric acid) Conditions: Heat The OH group and a H atom from an adjacent C atom is removed and a double bond is formed in the carbon chain A common example is the dehydration of ethanol: $\text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{CH}_2=\text{CH}_2 + \text{H}_2\text{O}$ Change in functional gp. Alcohol Alkene</p><p>Phosphoric acid does not appear in the equation as the water formed dilutes the concentrated phosphoric acid</p></div> <div>H₃PO₄ acts both as a dehydrating agent and as a catalyst</div>
	10.18	<p>understand that potassium dichromate(VI) in dilute sulfuric acid can oxidise:</p> <ul style="list-style-type: none">i primary alcohols to produce aldehydes (which give a positive result with Benedict's or Fehling's solution) if the product is distilled as it formsii primary alcohols to produce carboxylic acids (which give a positive result with sodium carbonate or sodium hydrogencarbonate) if the reagents are heated under refluxiii secondary alcohols to produce ketones <p><i>In equations, the oxidising agent can be represented by [O].</i></p>
	<p>Oxidation of Alcohols Reagents: acidified $\text{K}_2\text{Cr}_2\text{O}_7$ (potassium dichromate(VI)) + dilute H_2SO_4 (sulfuric acid) Orange ($\text{Cr}_2\text{O}_7^{2-}$) to Green ($\text{Cr}^{3+}$)</p>	

I - Primary alcohols to form Aldehydes (RCHO)

An aldehyde's name ends in -al (Ethanal) It always has the C=O bond on the first carbon of the chain so it does not need an extra number

Conditions:

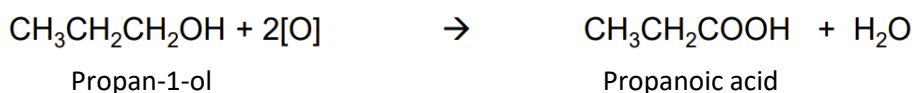
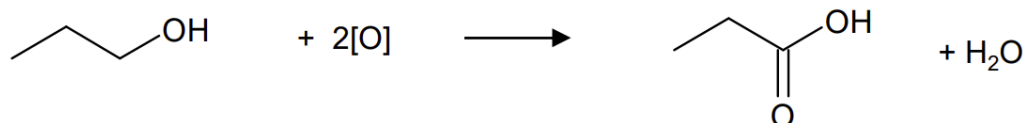
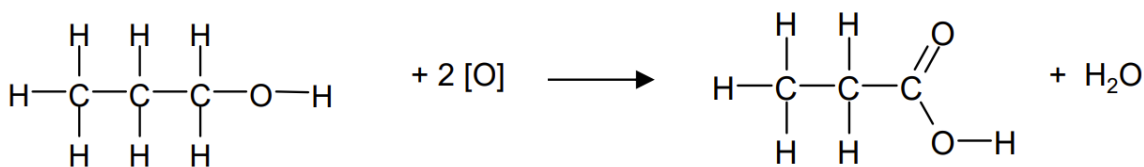
Warm gently with limited amount of $K_2Cr_2O_7$ and distill out the aldehyde as it forms



II - Primary alcohols to form Carboxylic Acids (RCOOH)

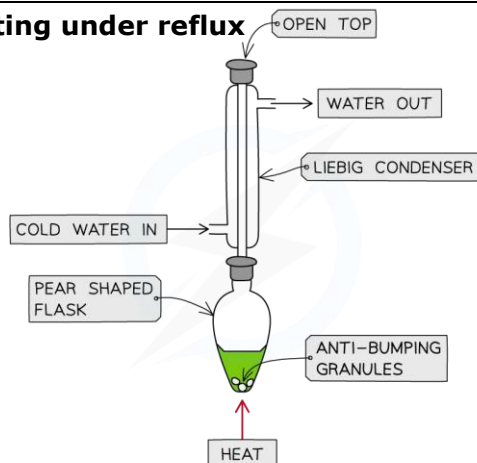
Conditions:

Heat under reflux with excess $K_2Cr_2O_7$ and distill only after the reaction has finished



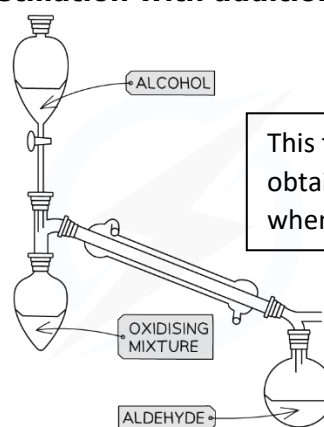
The Aldehydes (**RCHO**) formed are easily oxidized, more so than alcohols, so they undergo further oxidation to form carboxylic acids (**RCOOH**) that's why they need to be distilled out as they form

Heating under reflux



This technique is used to obtain a ketone or a carboxylic acid (i.e. when oxidation is complete)

Distillation with addition



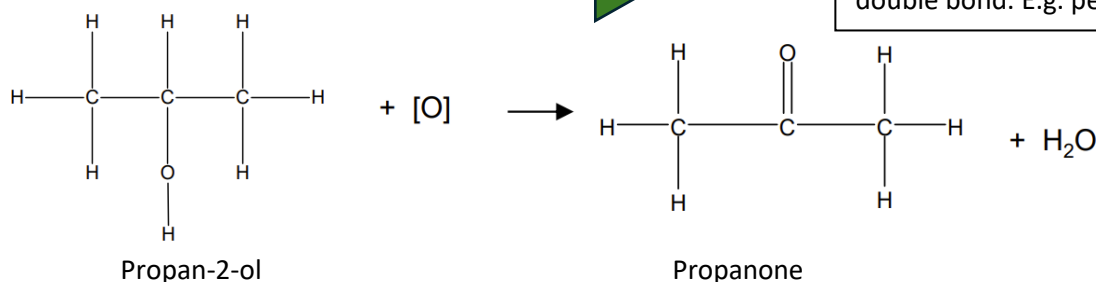
This technique is used to obtain an aldehyde (i.e. when oxidation is partial)

III - Secondary alcohols to form Ketones

(RCOR)

Ketones end in -one (Propanone) When ketones have 5C's or more in a chain then it needs a number to show the position of the double bond. E.g. pentan-2-one

Conditions: Heat under reflux



!Tertiary alcohols do not undergo oxidation (because there is no hydrogen atom bonded to the carbon with the OH group)

How to distinguish between Aldehydes and Ketones

Tollens' Reagent

Reagent: silver nitrate in excess ammonia solution (ammoniacal silver nitrate sol.)
 Conditions: warm gently
 Reaction: Only aldehydes can be oxidized to a carboxylic acid and the Ag^+ ions are reduced to Ag atoms (silver mirror/ black ppt)
 Ketones cannot be oxidized so will give a negative result

Fehling's Solution (Benedict's solution)

Reagent: alkaline solution containing blue Cu^{2+} ions
 Conditions: warm gently
 Reaction: Only aldehydes can be oxidized to a carboxylic acid and the Cu^{2+} ions are reduced to Cu^+ ions (the blue solution turns opaque due to the formation of a (brick) red precipitate, copper(I) oxide)
 Ketones cannot be oxidized so will give a negative result

10.19

understand, the following techniques in the preparation and purification of a liquid organic compound:

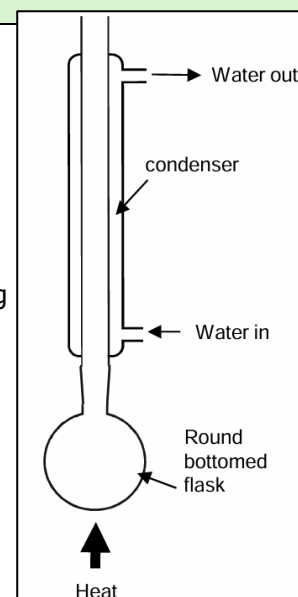
- i heating under reflux
- ii distillation
- iii boiling temperature determination
- iv extraction with a solvent using a separating funnel
- v drying with an anhydrous salt

i

Heat under reflux

- Refluxing is used to ensure complete reaction/ oxidation
- Heat the reaction mixture at a constant temperature in a **pear-shaped or round bottomed flask**
- The condenser prevents organic vapours from escaping by condensing them back to liquids
- **Anti-bumping granules** are added to the flask in both reflux and distillation to promote smooth boiling by providing a nucleus for gas bubbles to form on, making small bubbles form instead of large bubbles
- The top end of condenser is **never sealed** as the buildup of gas pressure could cause the apparatus to explode
- Example reactions:
 - Production of a carboxylic acid from a primary alcohol using acidified potassium dichromate
 - Production of an ester from an alcohol and carboxylic acid in the presence of an acid catalyst

Advantages:
 Heating at constant temp. prevents side reactions
 Condenser prevents loss of solvent



ii

Simple Distillation

for liquids with a difference in boiling point of more than 25°C

Don't forget to draw anti-bumping granules in the exam!

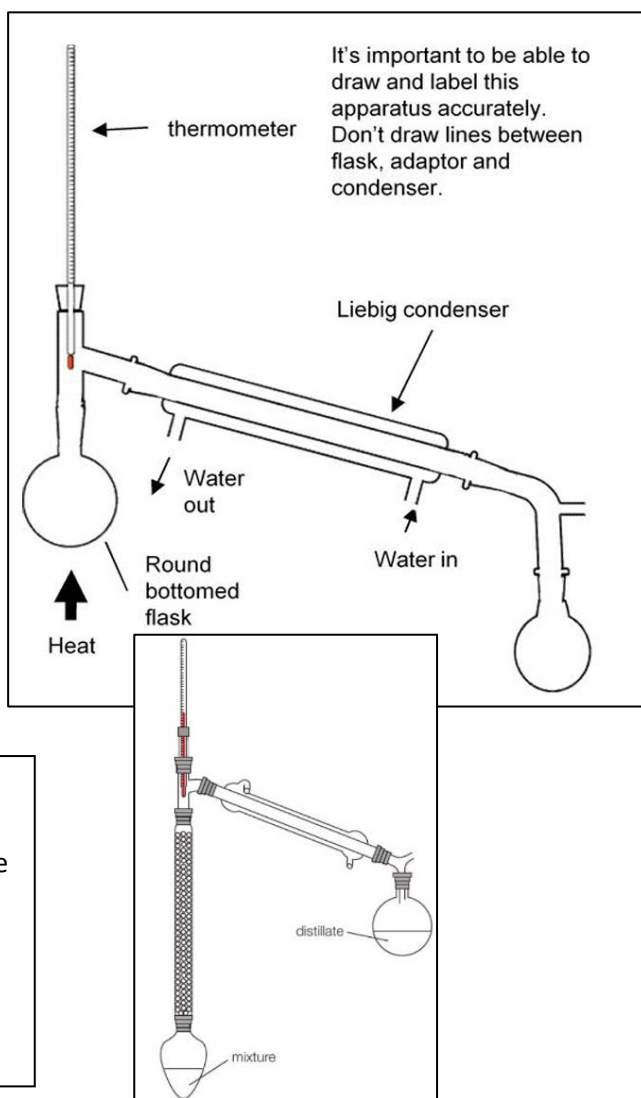
(Simple) Distillation

- In general, it is used to separate an organic product from its reacting mixture based on their boiling points in a **pear-shaped or round bottomed flask**
- Collect the distillate at the approximate boiling temperature range of the desired liquid
- **Anti-bumping granules** are added to promote smooth boiling
- Boiling temperature range between the two liquids must be large

Example reaction: Production of an aldehyde from a primary alcohol using acidified potassium dichromate solution

Fractional Distillation

The fractionating column full of glass beads act as surfaces on which the vapour leaving the column can condense on, then it can be evaporated again as more hot vapour passes up the column (this provides a better separation of liquids with small differences in boiling temperature)



iii

Boiling temperature determination

- For liquids, impurities increase the boiling temperature
- You can measure the boiling temperature and compare with data book values
- This is a test for purity: if boiling point is sharp, sample is likely to be pure
- If there is a range of boiling points, sample contains impurities

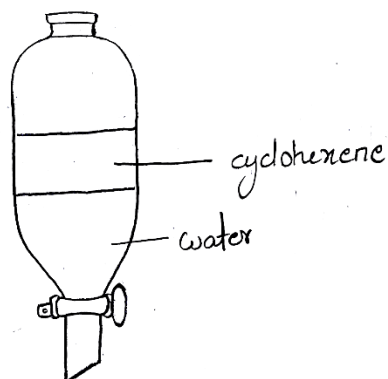
iv

Solvent Extraction

- Mix the mixture to be separated with a suitable solvent in which the desired organic product is more soluble in a separating funnel
- The desired organic compound will then move into the solvent layer where it is most soluble, leaving behind other impurities in the original mixture layer
- The two layers are then separated by running off the layers into separate flasks
- The desired organic compound can then be isolated from the solvent by distillation

Suitable Solvent

The solvent added should be immiscible (does not mix) with the original mixture
Desired organic product should be very soluble in this new solvent



Water is usually produced along with the organic product in reactions
This water will form an aqueous layer while the product will often be in the organic layer
Often, sodium carbonate is also added to neutralize or to remove impurities by washing
A stopper is placed in the neck of funnel and it is inverted and the tap is opened to release pressure (gas)
The funnel is returned to its upright position, the layers are allowed to separate and the aqueous layer is run off

v	<p>Drying</p> <ul style="list-style-type: none"> - An organic solid can be dried by simply leaving in a warm place or in a desiccator with a drying agent - An organic liquid will need a suitable drying agent such as anhydrous inorganic salts to remove traces of water from it - Anhydrous calcium chloride (or magnesium sulfate or calcium sulfate) are mixed with the impure organic product until its appearance changes from cloudy to clear, indicating that it is now dry - Then the drying agent is separated by filtration or decantation
10.20	<p>CORE PRACTICAL 7</p> <p>The oxidation of propan-1-ol to produce propanal and propanoic acid.</p>
	<ul style="list-style-type: none"> - Add 20cm³ of acidified potassium dichromate(VI) solution to a 50cm³ pear-shaped flask and cool the flask in an iced water bath - Place anti-bumping granules into the pear shaped flask - Use a pipette to slowly add the propan-1-ol dropwise into the reflux condenser - Then, remove the ice bath and allow to warm to room temperature and then use a water bath to heat the flask for 20 minutes - Purify the product using distillation <div data-bbox="1023 573 1497 1048"> </div> <p>For Core Practicals, you are advised to use the Lab Book!</p>
	<p>Further suggested practical:</p> <p>Investigation of reactions of primary and secondary alcohols, including propan-1-ol and propan-2-ol</p>

10D: Mass spectra and IR

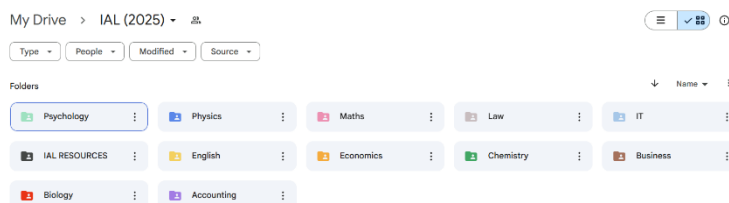
Students will be assessed on their ability to:

10.21	be able to interpret data from mass spectra to suggest possible structures of simple organic compounds using the m/z of the molecular ion and fragmentation patterns
10.22	<p>be able to use infrared spectra, or data from infrared spectra, to deduce functional groups present in organic compounds, and predict infrared absorptions, given wavenumber data, due to familiar functional groups including:</p> <ul style="list-style-type: none">i C–H stretching absorptions in alkanes, alkenes and aldehydesii C=C stretching absorption in alkenesiii O–H stretching absorptions in alcohols and carboxylic acidsiv C=O stretching absorptions in aldehydes, ketones and carboxylic acidsv C–X stretching absorption in halogenoalkanesvi N–H stretching absorption in amines
10.23	CORE PRACTICAL 8 Analysis of some inorganic and organic unknowns.
	<p>If the sample to be found is a solid, first dissolve it in deionized water and make it into an aqueous solution</p> <p>Testing for Ammonium ions (NH_4^+)</p> <ul style="list-style-type: none">- Add 10 drops of sample into a test tube and then add 10 drops of aqueous sodium hydroxide solution using a pipette- Swirl the mixture to ensure it is mixed well- Warm the mixture using a water bath- Hold a damp red litmus paper near the mouth of test tube- Positive test: Ammonia gas produced turns damp red litmus paper blue <p>Testing for Carbonate ions (CO_3^{2-})</p> <ul style="list-style-type: none">- Add 1cm^3 of dilute hydrochloric acid to a test tube using a pipette- Add 1cm^3 of the sample into the test tube- As soon as the sample is added, place a bung with a delivery tube to transfer the gas released into a different test tube containing lime water (calcium hydroxide)- Positive test: Carbon dioxide produced turns limewater milky <p>Testing for Sulfate ions (SO_4^{2-})</p> <ul style="list-style-type: none">- Add dilute hydrochloric acid to the sample- Then, add a few drops of barium chloride (or nitrate) solution- Positive test: White precipitate is formed <p>Flame Tests</p> <p>Refer to 8.17 pls thank you!</p>

Remarks

- Disclaimer: These Self-Study Booklet series are by no means intended to be a textbook replacement but instead are meant to be used alongside it
- This booklet is primarily exam-based and has been produced for last-minute revision in your exams by making the information in the syllabus into a simpler and more compact form factor
- **AND YOU ARE ADVISED TO USE THE LAB BOOK FOR CORE PRACTICALS AND FURTHER SUGGESTED PRACTICALS** which will not be covered in this booklet
- Thank you all for using this Self-Study Booklet and if you would like to find more resources like this one, do check out this google drive:
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- You will be redirected here:

(Note that there are only Self-Study Booklets/ CAQs for Physics and Chemistry)



- Do keep in mind that this is still a work-in-progress and you are welcome to add more resources to it- just drop a text to @aeth_en on discord!

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